INVESTIGATION OF FATIGUE RELATED MOTORCYCLE CRASHES – LITERATURE REVIEW (RSD-0261)

Report to VicRoads

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Preface

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EXECUTIVE SUMMARY

This report was commissioned by VicRoads to investigate the extent to which fatigue may contribute to motorcycle crashes. The project reviews the research into fatigue and road safety since the 2001 publication of the National Transport Commission report *Fatigue Expert Group: Options for Regulatory Approach to Fatigue in Drivers of Heavy Vehicles in Australia and New Zealand*, with particular emphasis on motorcyclists. The report outlines how fatigue affects motorcycle riders, its probable contribution to motorcycle crashes and the crash risk for motorcyclists of fatigue.

The review reveals that most recent driver fatigue research can be categorised into the following categories:

- investigations of the role of fatigue in road crashes
- studies of how to measure fatigue in crashes
- studies of how to detect fatigue
- studies regarding the nature of fatigue
- studies that examine the effectiveness of fatigue countermeasures and
- studies that examine fatigue in relation to specific populations.

Overall, it appears that over the past five years research has continued to refine knowledge in regard to the nature of fatigue and its effects upon driving. However, the increased focus upon the development of fatigue detection technologies and further countermeasures is probably the most noteworthy aspect of recent developments in pragmatic terms. Continued focus upon 'at risk' populations is needed. In this regard, little is currently known about fatigue in relation to motorcyclists.

Our review of the literature relevant to fatigue in motorcycling has identified a number of factors that appear to increase or decrease the role of fatigue in motorcycling. In general, there is a lack of good scientific investigation of these factors in specific regard to motorcycling and the likely extent of their importance. Nevertheless, they are listed here.

The factors that appear to **increase** the likelihood of fatigue in motorcycling include:

- The physical effort needed to control the motorcycle
- The extra concentration on the road surface required
- The extra concentration on other road users required
- The effects of heat and cold on alertness levels
- The effects of alcohol or drugs.

In addition, some factors increase the likelihood that a motorcycle crash will occur when the rider is fatigued (e.g. instability of the vehicle) or increase the severity of an incident such that it is more likely to be recorded as a crash (e.g. lack of protection to the rider).

The factors that appear to **decrease** the likelihood of fatigue in motorcycling include:

- The excitement and exhilaration associated with riding
- The low prevalence of riding during the late night-early morning period
- The low prevalence of riding for work with associated demands not to take breaks
- The low prevalence of long trips.

On the basis of the limited available evidence, it is possible to modify the diagram developed for truck drivers in the Fatigue Expert Group report (NTC, 2001) to better describe the factors contributing to fatigue in motorcycling. Figure 1 represents a preliminary attempt at such a modification. The right-hand-side of the diagram remains largely the same, with the title changed from "Driver factors" to "Rider factors" and the box labelled "Life away from work" relabelled as "Life activities". The left-hand-side of the diagram has been markedly changed. Instead of representing "Work factors", it now represents "Vehicle/Environment factors". The vehicle factors identified as affecting levels of rider fatigue include the cognitive demands of riding, vibration and noise and the physical demands of riding (the muscular fatigue components). The environmental factors identified as affecting levels of rider fatigue include heat and dehydration, cold and rain, and road surface irregularities (which increase the vibration and noise, and the physical and cognitive demands of riding as well).

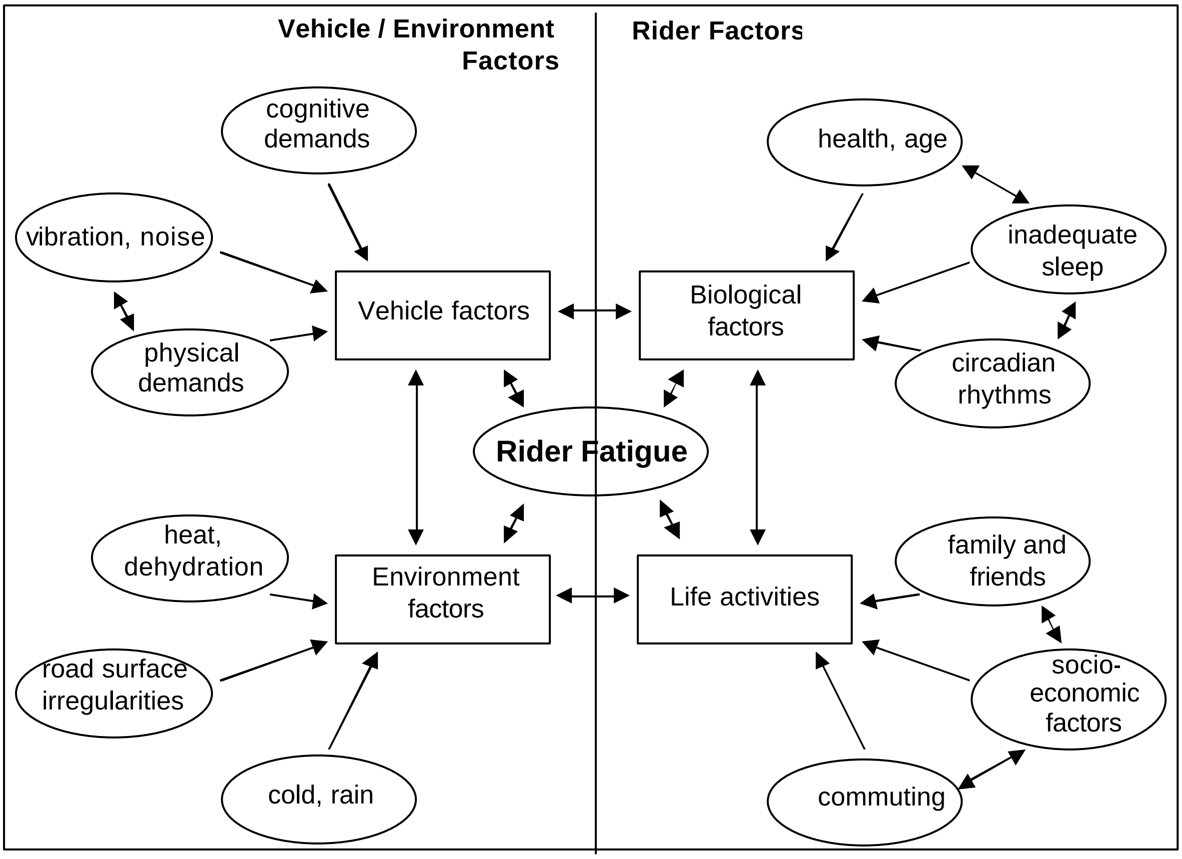

Figure 1 *Adaptation of diagram from NTC (2001) to show factors that potentially contribute to fatigue in motorcycling.*

The research concluded that we do not have the information needed to draw reliable conclusions regarding the magnitude of the effects of factors that potentially contribute to motorcycle fatigue or to assess the real contribution of fatigue to motorcycle crashes or the crash risk associated with riding while fatigued. However, the limited research suggests that fatigue is likely to be an issue in motorcycling, and therefore more knowledge of the phenomenon is needed to allow countermeasures to be developed.

More information is needed regarding:

- The extent to which riders experience both mental and physical fatigue and the circumstances under which these effects occur
- The rider, vehicle and trip factors that influence the development of mental and physical fatigue
- The degree to which the excitement and exhilaration of riding do offset fatigue
- The extent to which riders believe fatigue has contributed to their crashes and near-misses
- Methods of preventing or reducing mental and physical fatigue.

It is recommended that the following research activities be undertaken in the short term:

- Further analysis of motorcycle crash data to assess the likely validity of using the Australian Transport Safety Bureau (ATSB) fatigue definition with motorcyclists.
- Examination of motorcycle fatality data from the National Coronial Information Service to assess whether this data allows a better estimation of the role of fatigue in fatal motorcycle crashes.
- Surveying riders regarding their experience of fatigue when motorcycling. This could be undertaken as a mail, telephone or Internet survey.
- Undertaking testing of riders during trips to measure subjective levels of fatigue as a function of trip length, time of day etc. This could be undertaken naturalistically or designed as an experiment to provide additional control over confounding variables.

1. INTRODUCTION

1.1 BACKGROUND

This report was commissioned by VicRoads to investigate the extent to which fatigue may contribute to motorcycle crashes. In recent years, increased concern has been expressed in regard to fatigue in road users due to an enhanced awareness by governments and road safety professionals of the potential involvement of fatigue in road crashes. Of particular note, in 2001 the National Transport Commission (NTC) contracted the 'Fatigue Expert Group' to examine fatigue-related driving for heavy vehicle operators. Their report provided a sound review of pertinent issues and recommendations for the regulation of industry conditions affecting fatigue-related driving. However, whilst much research has been conducted in relation to fatigue in car and truck drivers, little is currently known about fatigue in relation to riding a motorcycle and the contribution of such to crash rates.

In 2005, fatal motorcycle crashes comprised 14% of the national road toll in Australia with 233 riders and pillions killed (ATSB, 2005). However, motorcycles only comprised 3% of all registered motor vehicles (ABS, 2005). Whilst fatalities for car drivers increased 3.3% from 2004 to 2005, motorcycle fatalities rose alarmingly by 18.9% over the same 12 month period (ATSB, 2005). The lack of protection offered by a motorcycle ensures that, in the event of a crash, motorcyclists are considerably more vulnerable to severe injuries than drivers of cars or trucks. When compared on the basis of deaths per kilometres travelled, the risk of fatal injury from a motorcycle crash is 29 times greater than that of other vehicles (Haworth & Mulvihill, 2005).

A combination of the disproportionately high injury rates for motorcyclists and the lack of knowledge in regard to how fatigue may specifically affect motorcyclists ensures that it is a topic that presently requires further investigation and clarification.

1.2 AIM OF THE PROJECT

The aim of the project is to investigate and report on the research into fatigue and road safety since the 2001 publication of the National Transport Commission report *Fatigue Expert Group: Options for Regulatory Approach to Fatigue in Drivers of Heavy Vehicles in Australia and New Zealand*, with particular emphasis on motorcyclists. The report outlines how fatigue affects motorcycle riders, its probable contribution to motorcycle crashes and the crash risk for motorcyclists of fatigue.

1.3 STRUCTURE OF THE REPORT

The report will initially outline the nature of fatigue in relation to road crashes then review literature published since the fatigue expert group paper (NTC, 2001) in an endeavour to identify recent developments. This will include a discussion of contributory factors, performance decrements, and the development of countermeasures designed to combat the problem.

Chapter 3 will focus on possible effects of fatigue that are specific to motorcyclists and the qualitative differences that may be present between rider fatigue and driver fatigue. This will be followed in Chapter 4 by a discussion of data sources used to identify and quantify rider fatigue. Estimates of fatigue-related crash risk for motorcyclists will follow based on official crash data. Finally, the findings will be discussed and recommendations put forth.

2. REVIEW OF RECENT FATIGUE LITERATURE

Whilst fatigue is considered an important contributing factor in road crashes, the lack of a consistent definition has made it difficult to accurately quantify the extent of the problem. As such, it is considered important to initially clarify the nature of fatigue and review the key issues. This chapter then outlines the factors contributing to driver fatigue proposed by the Fatigue Expert Group (NTC, 2001). The methods used in searching the literature for more recent research are then described, followed by a summary of how more recent research has modified our understanding of driver fatigue.

2.1 DEFINING FATIGUE IN THE ON-ROAD CONTEXT

Unfortunately there is no universally accepted definition of fatigue within the field of road safety. However, fatigue is commonly defined in terms of a *subjective* state (e.g. tiredness) and/or *objective* measurable performance decrement (e.g. increased reaction time).

The Fatigue Expert Group (NTC, 2001) defined driver fatigue in terms of the following two dimensions:

> "Impaired performance (loss of attentiveness, slower reaction times, impaired judgement, poorer performance on skilled control tasks and increased probability of falling asleep) and subjective feelings of drowsiness or tiredness.
>
> Long periods awake, inadequate amount or quality of sleep over an extended period, sustained mental or physical effort, disruption of circadian rhythms……inadequate rest breaks and environmental stress (such as heat, noise and vibration)".

Alternately, a recent report by Harrison (2006, p2) described fatigue in the on-road context as such;

> "….driving while fatigued will include driving under the effects of inadequate sleep, driving at times of the day when normal circadian rhythms would have the driver asleep, and driving without a break for a long time period. Fatigue may or may not, therefore, involve a subjective state of sleepiness, and may or may not involve total or partial sleep deprivation".

A distinction may also be made in terms of mental fatigue or physical fatigue (Brown, 1994) which may be particularly relevant when comparing rider fatigue and driver fatigue. Additionally, surrogate measures are often used by reporting agencies to define fatigue-related crashes (see Chapter 4).

2.2 A CONCEPTUAL MODEL OF FATIGUE IN THE ON-ROAD ENVIRONMENT

The Fatigue Expert Group (NTC, 2001) developed a model to highlight the key influences on fatigue for professional heavy vehicle drivers (see Figure 2.1). Whilst it is apparent that some aspects of the model are not particularly relevant to motorcyclists, it provides a sound framework to conceptualise possible contributory factors.

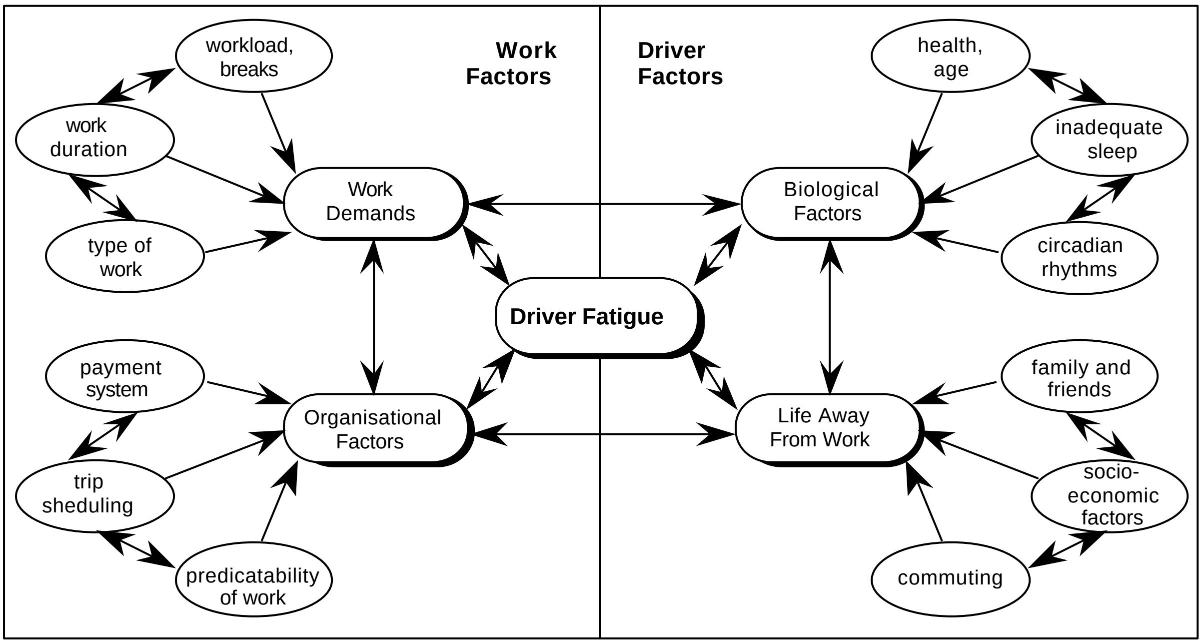

Figure 2.1 *Factors contributing to heavy vehicle driver fatigue. Source: National Transport Commission (2001).*

2.3 AN OVERVIEW OF THE KEY ISSUES

2.3.1 The effects of fatigue

The deleterious effects of fatigue that are linked to impairment of driver performance are apparent in terms of :

- increased response time
- decreased vigilance
- poor lane control
- poor speed control
- decreased tolerance of other road users
- diminished situational awareness
- microsleeps
- possible hallucinations.

Additionally, physiological measures indicate changes in:

- brain wave activity
- eye movement
- head movement
- muscle tone
- heart rate.

Self-reported changes in subjective state are also commonly noted in regard to driver fatigue. These include sleepiness/drowsiness, tiredness (physical or mental), lack of ability to concentrate, and diminished alertness/arousal. However, whilst a person may report one or more subjective feelings of fatigue, performance may not necessarily be degraded. Fairclough (2001) asserts that this is due to effort regulation whereby some drivers compensate by asserting increased mental effort when feeling fatigued. This is questionably only a short-term remedy as increased effort will eventually lead to increased fatigue.

Conversely, and more importantly, a person who shows diminished performance due to fatigue may not actually be aware that they are fatigued (Harrison, 2006; Matthews & Desmond, 2002). The implication for such is that a crash may ensue without the driver being aware of their fatigued condition.

2.3.2 Contributing factors

Sleep deprivation

There is a common misconception that fatigue only affects road users after lengthy periods of driving/riding (Harrison, 2006). However, a prior lack of adequate sleep may render vehicle operators in a fatigued state from the time they actually take control of the vehicle. Hence, even on short trips driver performance may be impaired due to a lack of sleep (Philip et al., 2005).

Cumulative sleep loss, whereby inadequate amounts of sleep are obtained over several days, results in an acquired sleep debt which may also impair driver performance. This is particularly relevant to young drivers whose lifestyle has been found to result in irregular sleep (Harrison, 2006). Sleep disorders (e.g. sleep apnoea) also contribute to sleep loss and subsequent road crash involvement (Connor, Whitlock, Norton, & Jackson, 2001). Sleep loss is also particularly relevant within the transport industry where drivers are commonly subject to poor sleep routines (NTC, 2001). For example, Gander, Marshall, James, and Quesne (2006) examined 511 truck crashes in New Zealand and found several sleep-related indicators of fatigue to be prevalent in approximately 11% of crashes. Key factors were: driver continuously awake more than 12 hours; less than six hours sleep in the past 24 hours; and more than one week since the driver had two consecutive nights of adequate sleep.

Time on task

The amount of continuous time spent on tasks such as long distance driving is acknowledged as a major precursor to fatigue states (Queensland Travelsafe Committee, 2005). Performance has been shown to decline after as little as 40 minutes on a repetitive simulated driving task (Thiffault & Bergeron, 2003).

Desmond and Hancock (2001) distinguished *active* from *passive* fatigue states in that active fatigue states may be induced by prolonged perceptual and motor adjustments during the driving task whilst passive fatigue states are related to constant monitoring over time. Specific fatigue concepts such as vigilance and boredom can, therefore, be interpreted in relation to passive states. As such, it has been found that performance on basic driving task components (e.g. lane control) may deteriorate over time but more salient aspects such as hazard detection/avoidance may remain intact due to maintained vigilance (Van der Hulst, Meijman, & Rothengatter, 2001). However, concern has been expressed in regard to the development of many in-car devices such as cruise control that may promote understimulation of drivers (i.e. creating passive fatigue/decreased vigilance).

More recently it has been acknowledged that for professional drivers the "time on task" concept should be broadened to "time on duty" to incorporate non-driving duties such as loading and unloading as well as the driving component (Queensland Travelsafe Committee, 2005; Tzamalouka, Papadakaki, & Chliaoutakis, 2005). The fatigue expert group (NTC, 2001) recommended that no more than five hours of consecutive work should be undertaken by professional drivers without a break in order to minimise the effects of fatigue.

Time of day

Circadian rhythms are known to impact upon fatigue in vehicle operators in terms of the time of day that humans are biologically predisposed to sleep (Queensland Travelsafe Committee, 2005). High risk times are considered to be midnight to 6am, and 2pm to 4pm (NTC, 2001). This is particularly pertinent to shift workers and long-haul truck drivers who are often required to work during early morning hours (Rosa, 2001).

Trip characteristics

Characteristics of the trip are also known to contribute to driver fatigue as boredom and a lack of vigilance are more likely in monotonous road environments (Thiffault, & Bergeron, 2003). Oran-Gilad and Hancock (2005) assert that this is due to decreased mental effort in undemanding circumstances. As such, a lack of stimulation for the driver on any particular trip may result in passive fatigue (Desmond & Hancock, 2001).

Other characteristics of the trip such as the time of day the trip is undertaken, time since last sleep at commencement of trip, length of trip, and time between rest breaks will impact upon fatigue as discussed in previous sections. This highlights the need for effective pre-trip planning with regard to these issues.

2.3.3 Alcohol comparisons for level of impairment

Several studies have shown that performance decrements associated with fatigue are comparable to those experienced whilst under the influence of alcohol. For example, Williamson, Feyer, Mattick, Friswell, & Finlay-Brown (2001) found that after 28 hours of continued wakefulness participants' performance on a range of cognitive, motor, and reaction time tasks was equivalent to blood alcohol concentrations (BAC) of up to 0.1% (twice the legal limit for driving). Alternately, other studies have found performance after 24hrs of continued wakefulness to be comparative to a BAC of 0.05% (Falleti, Maruuf, Collie, Darby, & McStephen, 2003; Marruff, Falleti, Collie, Darby, & McStephen, 2005).

2.3.4 Countermeasures

Several different types of countermeasures have been promoted in an endeavour to reduce fatigue-related crashes. These include:

- Advertising campaigns
- Fatigue training/education
- Driver reviver rest stops
- Naps

- Caffeine
- Trip planning
- Regulation of driving hours for professional drivers
- Two-up driving for professional drivers
- Rumble strips and audible edge lines.

Whilst sleep is the only ultimate solution to fatigue, countermeasures that focus on limiting exposure to risk factors such as driving in the early morning hours and excessive time on task should help to reduce crashes (NTC, 2001). Additionally, in–vehicle technologies have been under development for some time in an endeavour to create commercially viable driver warning systems.

2.4 LITERATURE REVIEW METHODS

To examine recent issues for fatigue-related crashes a review of the literature since the Fatigue Expert Group's report (NTC, 2001) was undertaken. This involved a search of:

- academic journals included in Science Direct, Ebsco, Proquest, and Blackwell Synergy databases;
- TRIS online;
- Google scholar;
- Published government reports (e.g. ATSB, RACV, Queensland Travelsafe Committee);
- Conference proceedings.

The review reveals that most recent driver fatigue research can be categorised into the following categories (with selected studies cited):

1. ***investigations of the role of fatigue in road crashes*** (Dobbie, 2002; Bun, Slavova, Struttmann, & Browning, 2005; Connor et al., 2002; Connor, Whitlock, Norton, & Jackson, 2001; Queensland Travelsafe Committee, 2005; Williamson, 2005);
2. ***studies of how to measure fatigue in crashes*** (Gander, Marshall, James, & Le Quesne, 2006; Williamson, Feyer, Mattick, Friswell, & Finlay-Brown, 2001);
3. ***studies of how to detect fatigue*** (Campagne, Pebayle, & Muzet, 2004; Eriksson & Papanikolopoulas, 2001; Heitmann, Guttkuhn, Aguirre, Trutschel, & Moore-Ede, 2001; Lal & Craig, 2001; Lal, Craig, Boord, Kirkup, & Nguyen, 2003; Veeraraghavan & Papanikolopoulos, 2001; Yamaguchi et al., 2006);
4. ***studies regarding the nature of fatigue*** (Desmond & Hancock, 2001; Fairclough, 2001; Falleti, Maruff, Collie, Darby, & Mcstephen, 2003; Falou et al., 2003; Maruff, Falleti, Collie, Darby, & McStephen, 2005; Matthews, 2002; Matthews & Desmond, 2002; Mills, Spruill, Kanne, Parkman, & Zhang, 2001; Oron-Gilad & Hancock, 2005; Peters, 2005; Philip et al., 2005; Rosa, 2001; Thiffault, & Bergeron, 2003; Van der Hulst, Meijman, & Rothengatter, 2001);
5. ***studies that examine the effectiveness of fatigue countermeasures*** (De Valck, De Groot, & Cluydts, 2003; Durkin, Harvey, Hughson, & Callaghan, 2006; Fletcher, McCulloch, Baulk, & Dawson, 2005; Gander, Marshall, Bolger, & Girling, 2005; Heitmann, Guttkuhn, Croke, & Moore-Ede, 2005; Macchi, Boulos, Ranney, Simmons, & Campbell, 2002); and

6. ***studies that examine fatigue in relation to specific populations*** (Crum & Morrow, 2002; Harrison, 2006; Hartley & Arnold, 2001; Lam, 2003; Ma, Williamson, & Friswell, 2003; Morrow & Crum, 2004; National Transport Commission, 2005; Smith, Carrington, & Trinder, 2005; Swann, 2002; Tse, Flin, & Mearns, 2006; Tzamalouka, Papadakaki, & Chliaoutakis, 2005).

2.5 RECENT CHANGES IN KNOWLEDGE ABOUT FATIGUE

An overview of key fatigue issues in Section 2.3 of this report provided a brief summary of previous and current research. This section focuses upon how the body of knowledge in regard to fatigue in the driving environment has been enhanced over the past five years.

From reports such as the Queensland Travelsafe Committee (2005) investigation into fatigue related crashes and the RACV investigation of fatigue in young drivers (Harrison, 2006) there appears to be an increased focus by governments on the ***role of fatigue in crashes***. However, the lack of a clear definition still remains a problem in the endeavour to measure/quantify fatigue.

However, research regarding the ***detection of fatigue*** has shown promise. New technologies that focus on physiological/behavioural responses such as EEG, eye blinks/movement, head movement, and saliva testing (e.g. see Heitmann et al., 2001; Lal et al., 2003; Yamaguchi et al., 2006) continue to be perfected with a view to provide warning to drivers of potential fatigue. Further research evaluating the practical viability of such devices in a 'real world' context is, however, required. Application of such devices has great potential, particularly within the trucking industry (Rau, 2001).

There has been a continued focus on ***investigating the nature of fatigue*** and its effect on performance, with particular attention to the distinction between various factors that have been shown to induce fatigue states. Of note, there have been developments in regard to knowledge of how monotonous road conditions may induce fatigue (e.g. see Oron-Gilad & Hancock, 2005; Thiffault, & Bergeron, 2003) as distinct from pre-existing driver states (such as sleep deprivation) and time on task. Hence, by controlling the road environment the fatigue-related effects of other contributory factors may be minimised. As such, this information informs future engineering countermeasures to reduce monotonous driving conditions in the road environment.

Perhaps the most encouraging aspect of recent research is the ***development of countermeasures for driver fatigue***. To complement existing knowledge a variety of countermeasures have recently been trialled and found to be effective. These include:

- slow release caffeine (De Valck et al., 2003);
- in-seat vibration to restore alertness (Heitmann et al., 2001);
- fatigue training for professional drivers (Gander et al., 2005); and
- fatigue training for work schedulers in the transport industry (Heitmann et al., 2005).

Additionally, much of the previously mentioned new technology for detecting driver fatigue aims to inform continued development of driver warning systems. In this regard it is also apparent that there is an increased awareness of the need to tailor countermeasures to particular 'at risk' target groups.

Accordingly, the ***examination of fatigue in regard to specific populations*** is of note within the recent literature. For example, Harrison's (2006) study examining young driver fatigue highlighted that whilst many young drivers often felt tired they continued to drive. This finding was supported by Smith et al. (2005). An apparent misconception among many young drivers that fatigue is manageable combined with the influence of lifestyle/motivational factors are issues that may contribute to the increased risk for young drivers (Harrison, 2006). Given the overrepresentation of young drivers in fatigue-related crashes these findings are valuable in terms of guiding intervention design.

Overall, it appears that over the past five years research has continued to refine knowledge in regard to the nature of fatigue and its effects upon driving. However, the increased focus upon the development of fatigue detection technologies and further countermeasures is probably the most noteworthy aspect of recent developments in pragmatic terms. Continued focus upon 'at risk' populations is needed. In this regard, little is currently known about fatigue in relation to motorcyclists. The next chapter aims to discuss possible influences based on the available research and riders' subjective reports.

3. CONSIDERATION OF THE EFFECTS OF FATIGUE ON RIDERS

Whilst the body of research that has been conducted over the past twenty years has provided a sound understanding of driver fatigue, little is known about the specific nature of rider fatigue. This is an unfortunate oversight on behalf of governments and researchers, since up to 40% of riders have been found to experience fatigue on at least half of their long journeys (Ma et al., 2003). Potential qualitative differences between rider and driver fatigue may exist in terms of the physical demands that riders endure or the cognitive/perceptual demands associated with riding.

3.1 PHYSICAL DEMANDS

It is recognised that fatigue for car and truck drivers can be associated with the level of comfort provided by the vehicle. Paradoxically, fatigue may ensue from the driver being too comfortable (e.g. if the heater is on and driver is too relaxed) or from a lack of comfort (e.g. seat vibration for truck drivers).

3.1.1 Muscular fatigue

For motorcyclists a range of physical demands may potentially impact upon rider fatigue. Brown (1994) highlighted the different aspects of physical fatigue in terms of *static* and *dynamic* muscle fatigue. Dynamic muscle fatigue is the result of exhausting the muscle beyond its capacity to recover and perform as normal (Brown, 1994). Such fatigue is experienced with exercise that places demands on the muscles to contract and relax. As such, during typical on-road riding a motorcyclist would not normally experience this level of physical activity. However, if performing illegal acts such as racing through tight curves or stunts such as wheel-stands, it is not beyond reason that a rider may experience this type of physical fatigue if these activities were prolonged without rest.

Alternately, static muscle fatigue results from the body assuming a fixed position for an extended period. This is more likely the type of physical fatigue that would be associated with riding an on-road motorcycle. When riding a motorcycle, the rider is ostensibly restricted to the same position throughout the course of a journey in order to safely operate the vehicle. Furthermore, certain categories of motorcycles may be more subject to these ergonomic constraints than others. For example, the rider of a sports bike adopts a racing posture of leaning forward whilst the rider of a cruiser style motorcycle (e.g. a Harley Davidson) is typically more upright. Some motorcycles require the rider to tuck their legs up, whereas others offer a more extended leg position. Accordingly, tight/stiff muscles are commonly reported by riders from assuming a fixed position on long rides (Gillen, 1998; Motorcycle Council of NSW, 2006).

Brown (1994) asserted that static muscle fatigue in particular may distract operators from the cognitive demands of the required task. However, in an on-road examination of rider fatigue, Ma et al. (2003) found that whilst riders reported significant levels of physical fatigue, performance on vigilance and reaction time tasks was not diminished. As such, more research is required to ascertain whether this phenomenon is widespread.

3.1.2 Environmental influences

Motorcycle riders are exposed to a range of environmental factors that may impact upon fatigue states. Possible influences include wind, rain, cold climate, hot climate, vibration, noise, and road conditions. Exposure to some of these factors may also vary between categories of motorcycles. For instance, sports tourer style motorcycles commonly have fairings and screens to deflect the wind, while cruiser style motorcycles may expose the rider more in this regard and some models have historically been considerably noisier than other types.

Ma et al. (2003) found that monotonous road environments, vibration, and poor weather conditions were all factors that riders reported as causes of fatigue. Additionally, the Motorcycle Council of NSW (2006) warns that riders are prone to dehydration due to exposure to environmental elements. Whilst there is a lack of scientific evidence of the effects of environmental exposure on rider fatigue, there is some evidence in regard to these factors for truck and bus driver fatigue (see Evans, 1994; Mabbott, Foster, & McPhee, 2001; Taguchi, 1998). Accordingly, as riders are more directly exposed to the elements than either truck or bus drivers, it could be reasonably expected that these factors impinge upon the riders' ability.

3.2 COGNITIVE/PERCEPTUAL DEMANDS

The level of mental effort required when in control of a motorcycle is arguably higher than that required for driving a car (Motorcycle Council of NSW, 2006; RTA, 2004). This is possibly the case due to the substantial ramifications of loss of attention/concentration for riders. When in control of a motorcycle the operator needs to be constantly aware of the road environment and often predict the movements of other road users due to a general lack of awareness of motorcyclists by car drivers (RTA, 2004). As such, the heightened demand on cognitive resources whilst riding may result in energy expenditure and an increased potential for fatigue. Ma et al. (2003) found a significant increase in self-reported mental demand and effort for participants during a five hour ride compared to a non-riding day. However, at this point of time there is no direct research to confirm or disprove that riding is more mentally demanding than driving a car.

Alternately, some riders have reported increased alertness during riding. Tunnicliff (2005) investigated qualitative aspects of riders' experiences for a range of factors including fatigue. She found that some riders mentioned how exhilarating and refreshing it was to get on their motorcycles after a tiring days work and that their alertness levels were restored during the ride. Similarly, other riders reported getting a 'buzz' out of riding. This aspect of riding may possibly be linked to personal satisfaction and enjoyment that many riders experience which may serve as a short-term remedy for fatigue.

3.3 THE INFLUENCE OF ALCOHOL/DRUGS

Whilst the performance decrements associated with fatigue have been outlined earlier in this paper it is important to also consider the possible influence of alcohol and drugs on rider fatigue states. Drowsiness is a common effect of alcohol, cannabis, opiates, benzodiazepines, barbiturates, and medications such as antihistamines (McKim, 2003). The effects in regard to crash risk can be interpreted as causal (i.e. alcohol and/or drugs may induce fatigue states) or additive (e.g. where a lack of sleep is combined with alcohol).

Philip, Vervialle, Breton, Taillard, and Horne (2001) found that motor vehicle crashes were 6.8 times more likely to be fatal if controllers were under the influence of alcohol and fatigued compared to non-impaired controllers. Similarly, Mills, Spruill, Kanne, Parkman, & Zhang (2001) found that impairment was 'severe' when alcohol was combined with pre-existing fatigue compared to a 'modest' effect of alcohol alone.

In consideration of these issues a comparison of alcohol/drug involvement for riders compared to drivers is essential. In NSW in 2004, 19% of riders in fatal crashes had an illegal blood alcohol level, compared to 22% for other vehicle controllers (RTA, 2005). In Victoria over the period 2001 to 2004, 19% of fatal motorcycle crashes involved a BAC>.0.050 compared to 25% of all vehicle crashes. In serious injury and injury crashes, the percentages were lower but showed the same pattern of being lower for motorcycle crashes. Drummer (2003) found that similar percentages of riders and drivers were alcohol-positive in fatal crashes, however riders were twice as likely to show recent cannabis use. Haworth (2000) concluded that alcohol may play a smaller role in motorcycle crashes than in car crashes because of the largely daytime pattern of motorcycle riding. She reported that having a positive BAC for riders was associated with greater riding experience, unlicensed riding, riding a borrowed motorcycle, carrying a pillion passenger, illicit drug use, excessive speed and single-vehicle crashes.

The Melbourne motorcycle crash case-control study (Haworth et al., 1997) found that 11% of crashed riders and 8% of control riders had taken prescription drugs in the previous 12 hours. In addition, 2% of crashed riders and 3% of control riders had taken non-prescription drugs in the previous 12 hours. Cough and cold and hay fever medications were the most common non-prescription drugs reported. Interestingly, many of these drugs can cause drowsiness.

3.4 WORK-RELATED RIDING

Many of the factors identified by the Fatigue Expert Group as contributing to fatigue in professional heavy vehicle drivers were work-related (see Figure 2.1). While most motorcycles are used for recreation or commuting, there is some work-related use of motorcycles, particularly for mail deliveries, courier-type work and police enforcement. Motorcycles are also commonly used for farm work, but this is largely off-road use of motorcycles and therefore outside of the scope of this report. When motorcycles are used for work purposes, then some of the work-related contributing factors to fatigue that the Fatigue Expert Group report identified may be relevant.

Symmons and Haworth (2005) analysed crash and registration data for fleet and non-fleet vehicles in New South Wales. The registration data showed that at 30 June 2000, 14.4% of motorcycles were classed as fleet vehicles, compared with 15.5% of cars. In contrast, only 9.0% of motorcycles in crashes (781) were fleet vehicles. This suggests that fleet motorcycles have a lower crash involvement than non-fleet motorcycles, but whether this reflected differences in distances travelled is not known.

For fleet motorcycles, the most common crash type was same direction crashes (19%). A relatively high proportion of fleet motorcycle crashes were off-path (i.e. lost control without crashing into another vehicle) compared with the proportions for these crash types for the other vehicle types (15%-17% versus 2-9% respectively).

In addition to the fleet motorcycles mentioned, there were 16 police motorcycle crashes over the 5-year period 1995-2000 (1 fatal, 14 injury, 1 non-injury) but coding issues prevented the number of registered police motorcycles to be established. Overall, fatigue was implicated in 2.4% of all emergency vehicle crashes, compared with 3.2% overall for all fleet vehicles. The numbers of crashes involving fatigue was too small to analyse as a function of type of emergency service or driver age.

The motorcycle crash case-control study (Haworth et al., 1997) found the trip being non-work-related increased the risk of crash involvement (compared with work-related trips: odds ratio of 3.0). The size of the odds ratio decreased after adjusting for factors such as age, presence of alcohol and licence status but remained statistically significant.

3.5 FATIGUE AND TRIP LENGTH

The Fatigue Expert Group identified time on task as an important contributor to fatigue in professional heavy vehicle drivers. Trip length is a measure of time on task. In car drivers, many fatigue-related crashes occur during trips of less than two hours (Fell, 1995; Haworth & Rechnitzer, 1993). We might hypothesise that relatively few fatigue-related motorcycle crashes occur on short trips because the excitement and alerting nature of motorcycling may counteract circadian and other fatigue contributing factors over the short term. This is a hypothesis that could be tested, at least by asking riders about fatigue-related crashes (assuming that they are able to identify that fatigue contributed to the crash). Riders could be asked for details of their trip prior to the crash, such as time of commencement of the trip and time of crash, breaks taken, whether they felt tired prior to the crash, amount of sleep prior to the trip etc.

3.6 PRESENCE OF FATIGUE VERSUS CRASHING

Driver fatigue results in an identifiable pattern of deterioration in driver performance. Depending on environmental factors such as the width of the roadway and the presence or absence of other traffic, the deterioration in driver performance may or may not result in a crash. For motorcycles, there is the potential that an error induced by fatigue would be more likely to result in a crash (perhaps because of the instability of two-wheeled vehicles or because another road user failed to take notice and avoid the motorcycle). In addition, a crash from a fatigue-related action (or inaction) could result that might be relatively minor and thus not captured by the crash data system if the fatigued operator was driving a car, but would have more serious consequence for a motorcyclist because of the vulnerable nature of the rider. Certainly, the argument has been made that alcohol may increase crash risk at lower concentrations in the blood for motorcyclists than car drivers. It may be that lower levels of fatigue may increase crash risk for motorcyclists in an analogous manner.

3.7 BEYOND THE RESEARCH

Whilst little scientific research has been conducted regarding rider fatigue there is an awareness of the issue amongst rider groups and some government agencies. This lay understanding of rider fatigue is based on personal experiences of riders and is commonly shared over the internet.

Gillen (1998) conducted a brief qualitative internet survey of riders for fatigue issues. Whilst participant numbers were unacceptably low in terms of scientific research (n = 12), it confirmed that fatigue is certainly an issue for riders and provided rider perspectives on the nature of fatigue and how they deal with it. One aspect of the survey that was interesting was the mixed response in regard to the possible beneficial effects of screens in prevention of wind-related fatigue onset. Whilst some government agencies (Californian Department of Motor Vehicles, 2006; Gloucestershire County Council, 2006; New York Department of Motor Vehicles, 2006) advocate that screens are effective in combating fatigue, it appears from Gillen's results that this may be more a case of personal preference.

Other authors (Arthur, 2006; Ayres, 2006; Cutler, 2006; England, 2006; Friedman, 2006; Vaughan, 2006) share their views on rider fatigue on various web pages, many based on endurance rides of up to 1,000 miles (1,600 kms) in one day. Accordingly, it appears that completing long distance rides is somewhat a 'badge of honour' for some riders. Issues such as environmental conditions and the need to hydrate adequately are common among the above authors, suggesting that the physical demands of riding certainly impact upon rider fatigue. For example, the impact of cold weather on rider fatigue is mentioned by several independent authors, rider associations, and government agencies (Californian Department of Motor Vehicles, 2006; Gillen, 1998; Gloucestershire County Council, 2006; Park, 2006; Womens International Motorcycle Association, 2006).

3.8 COUNTERMEASURES AND STRATEGIES FOR RIDER FATIGUE

Some of the countermeasures that are designed to combat driver fatigue are also applicable to rider fatigue. These include breaks/naps, public education campaigns, pre-trip planning/routine (e.g. ensuring you have adequate sleep prior to commencement), and avoidance of driving/riding during circadian low points. However, there are particular considerations in this regard for motorcyclists. For example, whilst car/truck drivers are able to pull off the road to take a short nap in their vehicle this is less practical for a motorcycle rider. Additionally, during breaks it is probably more important for riders to ensure that they drink plenty of fluids to remain hydrated.

Other countermeasures are specific to riders and generally relate to rider comfort. One such option is modifying the motorcycle to decrease physical strain and stiffness (although legal requirements need to be considered). For example, throttle assists are available that are designed to relieve the pressure on the rider's hand and wrist from gripping the throttle on long rides (e.g. see Throttle rocker, 2006). Suspension, steering, and seat modifications may alleviate excessive vibration in the vehicle (e.g. see Ayres, 2006; Honda, 2006). Additionally, fairings and screens may relieve constant buffeting by winds (Arthur, 2006).

Beyond these factors there are a number of strategies that riders employ to combat fatigue. The Motorcycle Council of NSW (2006) recommends: that riders put their weight on the footpegs and lift their body off the seat; wiggle their toes to increase circulation; and shrug and rotate their shoulders. However, it must be noted that whilst these strategies may temporarily relieve the physical symptoms of fatigue, they do not provide a solution to the problem. Similarly, self-reported strategies include opening the helmet visor to increase oxygen intake and standing up while riding (Gillen, 1998). Perhaps an obvious strategy is to ensure that adequate warm clothing is worn to protect against extreme cold caused by wind chill. The Gloucestershire County Council (2006) recommend that riders carry an extra set of gloves inside their jacket as well as wearing appropriate weatherproof clothing. Additional strategies include wearing ear plugs to prevent excessive noise (Arthur, 2006) and ensuring screens and visors are clean to avoid eye strain (Friedman, 2006).

3.9 SUMMARY

Our review of the literature relevant to fatigue in motorcycling has identified a number of factors that appear to increase or decrease the role of fatigue in motorcycling. In general, there is a lack of good scientific investigation of these factors in specific regard to motorcycling and the likely extent of their importance. Nevertheless, they are listed here.

The factors that appear to **increase** the likelihood of fatigue in motorcycling include:

- The physical effort needed to control the motorcycle
- The extra concentration on the road surface required
- The extra concentration on other road users required
- The effects of heat and cold on alertness levels
- The effects of alcohol or drugs.

In addition, some factors increase the likelihood that a motorcycle crash will occur when the rider is fatigued (e.g. instability of the vehicle) or increase the severity of an incident such that it is more likely to be recorded as a crash (e.g. lack of protection to the rider).

The factors that appear to **decrease** the likelihood of fatigue in motorcycling include:

- The excitement and exhilaration associated with riding
- The low prevalence of riding during the late night-early morning period
- The low prevalence of riding for work (compared to driving heavy vehicles) with associated demands not to take breaks
- The low prevalence of long trips (more than four hours)

On the basis of the limited available evidence, it is possible to modify the diagram developed for truck drivers (shown earlier as Figure 2.1) in the Fatigue Expert Group report (NTC, 2001) to better describe the factors contributing to fatigue in motorcycling. Figure 3.1 represents a preliminary attempt at such a modification. The right-hand-side of the diagram remains largely the same, with the title changed from "Driver factors" to "Rider factors" and the box labelled "Life away from work" relabelled as "Life activities". The left-hand-side of the diagram has been markedly changed. Instead of representing "Work factors", it now represents "Vehicle/Environment factors". The vehicle factors identified as affecting levels of rider fatigue include the cognitive demands of riding, vibration and noise and the physical demands of riding (the muscular fatigue components). The environmental factors identified as affecting levels of rider fatigue include heat and dehydration, cold and rain, and road surface irregularities (which increase the vibration and noise, and the physical and cognitive demands of riding as well).

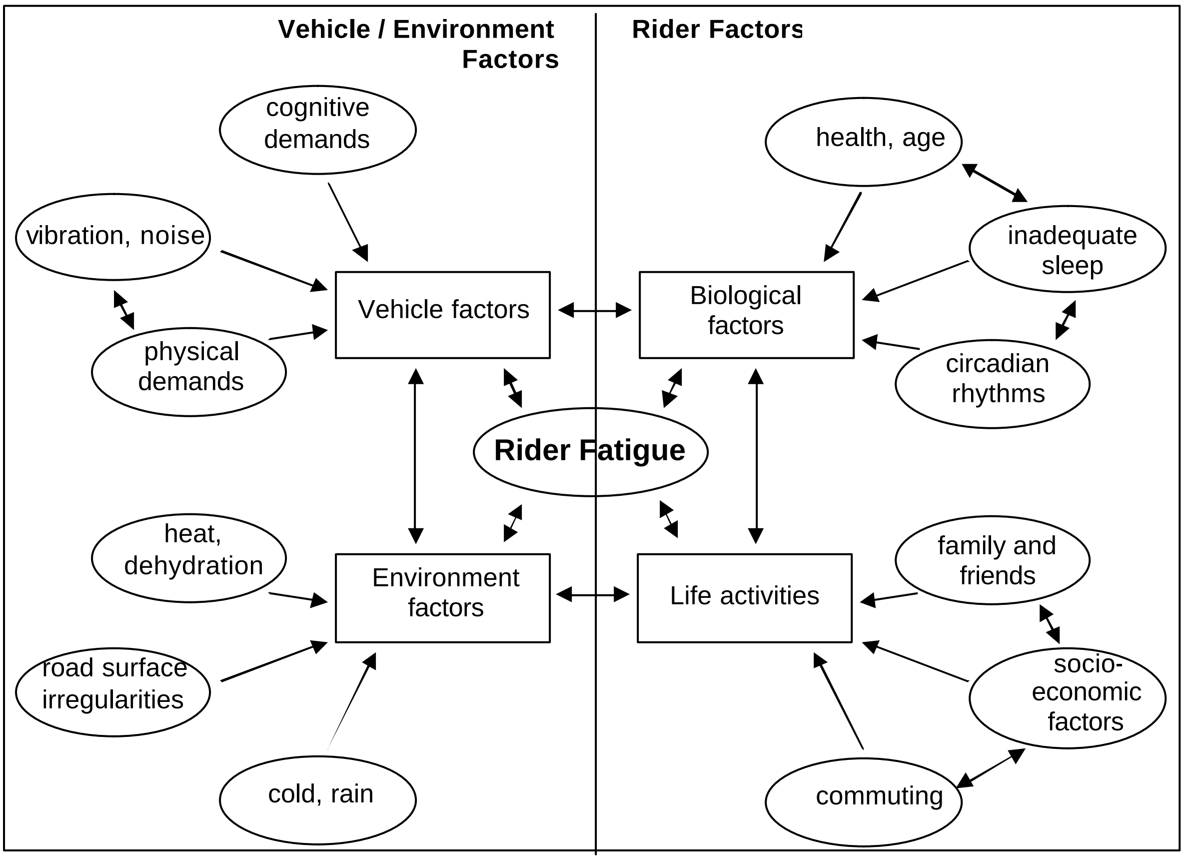

Figure 3.1 Adaptation of diagram from NTC (2001) to show factors that potentially contribute to fatigue in motorcycling.

4. IDENTIFICATION OF DATA SOURCES AND DATA ON MOTORCYCLE FATIGUE CRASHES

This chapter examines data sources and data to investigate what is known about motorcycle fatigue crashes and the extent to which fatigue contributes to motorcycle crashes. The data sources examined included:

- Police reports
- Coroner's reports
- In-depth crash studies
- Hospital data
- Exposure data..

The sources of motorcycle crash data in Victoria are summarised in Figure 4.1. The figure shows that information is only available for injury crashes and that not all crashes are reported to Police. The potential biases and limitations of each of the data sources are discussed in more detail in a paper assessing the validity of motorcycle safety data presented at the 2003 Road Safety Research, Education and Policing Conference (Haworth, 2003).

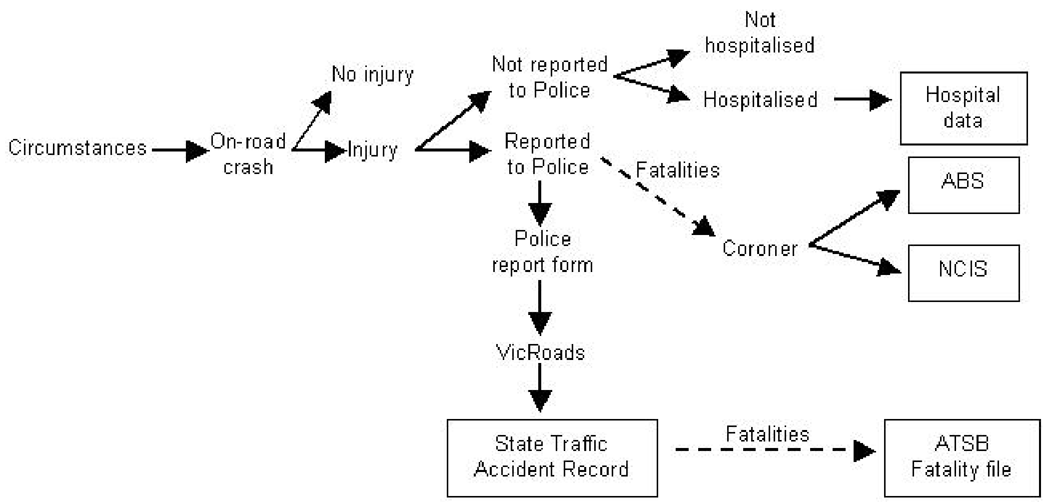

Figure 4.1 Summary of motorcycle crash data sources in Victoria (from Haworth, 2003).

4.1 POLICE CRASH REPORTS

Police reports entered into crash data systems are the only data available for most traffic crashes. In some States (including New South Wales and Queensland), police check a box on the accident report form to indicate that fatigue was considered to be a contributing factor in the crash. The figures derived from such coding are considered to be an underestimate of the true number of fatigue-related crashes (Attewell, Lock, Dobbie & Walker, 2001).

In this section, police crash data from NSW and Queensland are presented first and their proxy definitions described. The validity of these proxy definitions is then discussed, along with a more recent operational definition of fatigue developed by the ATSB. Data from Victoria are then presented.

4.1.1 NSW RTA data

The New South Wales Roads and Traffic Authority has developed an algorithm using information routinely recorded in crash data to determine fatigue-related crashes. According to RTA guidelines, fatigue is judged to have contributed to the crash if:

- the vehicle's controller was described by police as being asleep, drowsy or fatigued,
- the vehicle was involved in a head-on crash while travelling on the wrong side of the road (but was not overtaking and there were no other relevant mitigating circumstances), or
- the vehicle ran off the road (a straight section or the outside of a curve) but the vehicle was not considered to be travelling at an excessive speed.

Using the RTA's definition, fatigue was a factor in 7% of motorcycle riders in fatal crashes in 1998-2002. This was lower than the 12% of fatal crashes of other motor vehicle controllers (largely car drivers) that involved fatigue (RTA, 2004).

The RTA has produced a document *Motorcycle safety: Issues and countermeasures* that provides some useful data (RTA, 2004). It notes that 66% of motorcycle casualty crashes occur on weekdays, with almost a quarter of crashes occurring from 3pm to 7pm. The remaining third of motorcycle crashes occur on the weekend, with about half of these occurring between 11am and 5pm. The characteristics of these crashes also appear to differ. The RTA identified 10 routes with the highest number of motorcycle casualties in 1998-2002. One group were key arterial routes within the Greater Sydney metropolitan area where crashes frequently involved multiple vehicles and occurred during afternoon peak hours. The second group were popular country and recreational routes where crashes were more likely to involve a single vehicle, occur on the weekend in the early afternoon, involve speeding and the motorcycle running off path on a curve. This is indicative of possible fatigue during the afternoon circadian low with riders potentially losing concentration during critical manoeuvres. However, a number of other potential influences such as inexperience cannot be discounted.

4.1.2 Queensland crash data

Queensland Transport defines a 'driver fatigue crash' as:

- Where the reporting police officer identifies a contributing circumstance is a driver or rider who fell asleep or is otherwise attributed with fatigue
- Single vehicle crash within a speed zone of 100 km/h or greater, between 2pm to 4pm or 10pm to 6am (typical fatigue times)
- Crashes often involve a vehicle leaving the roadway with the driver not attempting to avoid the crash

An analysis of Queensland crash data for 2001-2005 was undertaken using the Webcrash2 program. Figure 4.2 shows that there were relatively few motorcycle rider and pillion casualties between midnight and 6am and that the number of casualties peaked in the late afternoon.

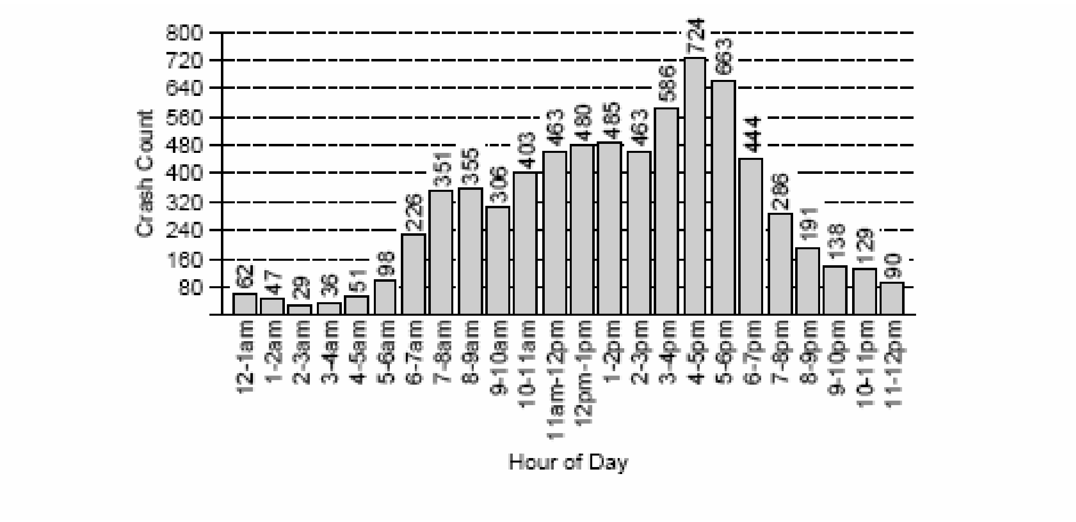

Figure 4.2 Motorcycle rider and pillion casualties by time of day, Queensland 2001-2005 (source Webcrash 2, Queensland Transport).

When the Queensland fatigue definition was applied to the rider and pillion casualties, a total of 136 (1.9%) were identified as 'fatigue-related' (although 5.7% of fatalities were 'fatigue-related'). Figure 4.3 shows that the bulk of these 'fatigue-related' casualties occurred between 2pm and 4pm. Figure 4.4 shows the patterns were similar for all severity levels.

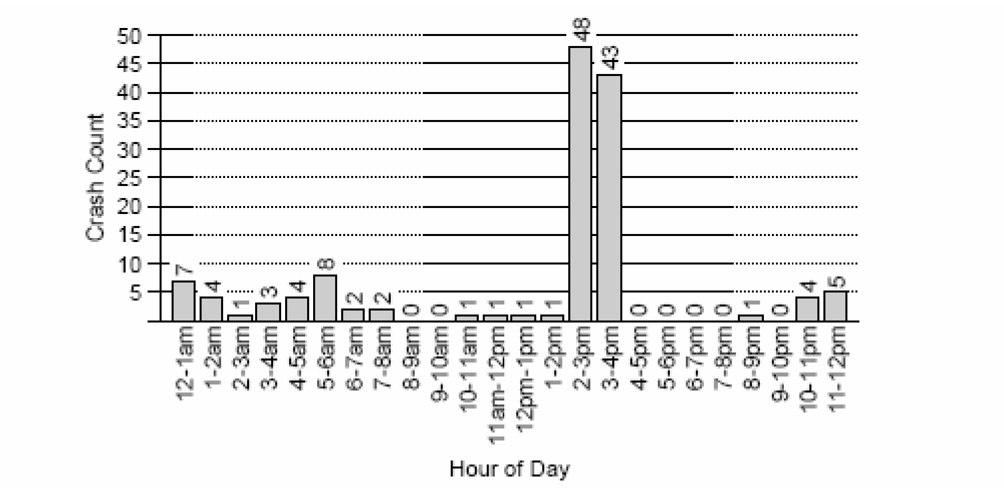

Figure 4.3 Fatigue-related rider and pillion casualties by time of day, Queensland 2001-2005 (source Webcrash 2, Queensland Transport).

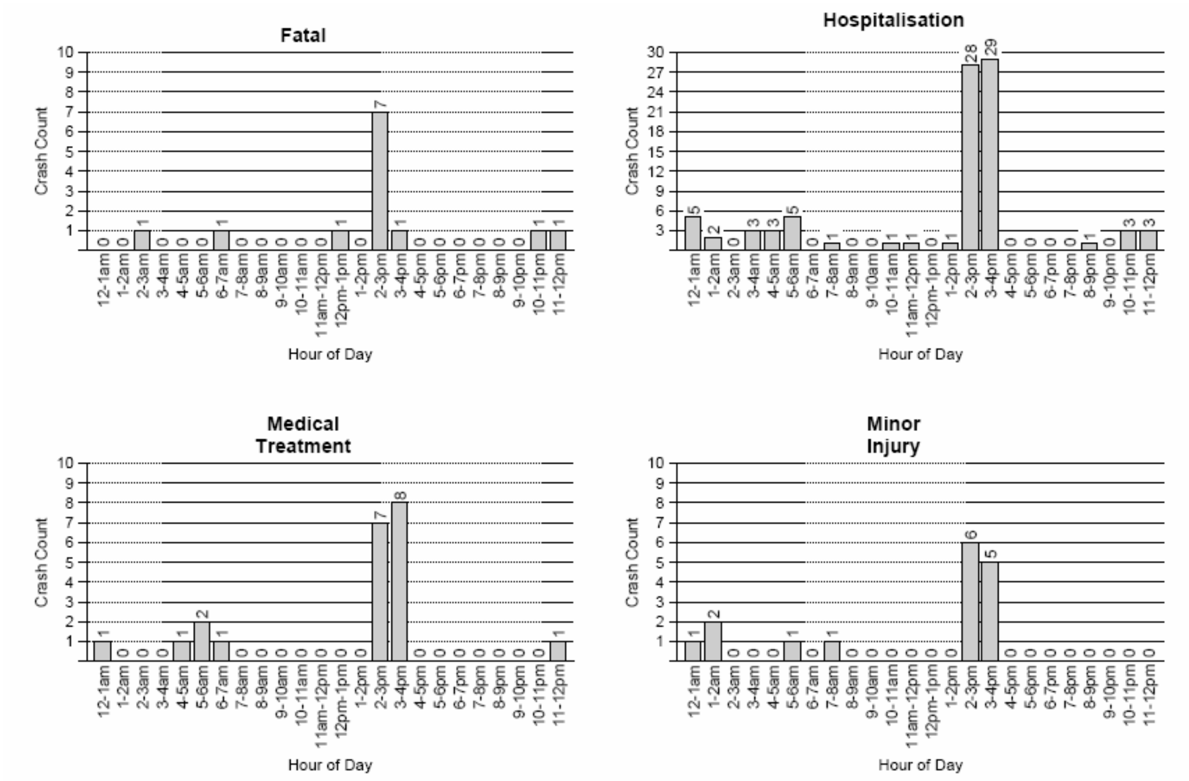

Figure 4.4 Fatigue-related rider and pillion casualties by severity by time of day, Queensland 2001-2005 (source Webcrash 2, Queensland Transport).

The overlap with drink driving crashes is evident in Queensland data because 12 of the 46 fatalities (29%) during 2005 which were identified as 'fatigue-related' involved alcohol or other drugs. In addition, 37% involved 'inattention' and 24% involved 'speed'.

Of the 64 motorcyclist fatalities in 2005, the most commonly identified factors in these crashes were speed (30%), inattention (30%) and alcohol/drugs (17%). Some of the crashes coded as involving inattention may have involved fatigue.

4.1.3 Testing the validity of fatigue proxy measures

While fatigue proxy measures are used in several States, their validity has been questioned by some research. As yet no research has examined their validity for motorcycle crashes.

Cercarelli and Haworth (2002) examined police reports of road crashes to determine how best to identify fatigue-related crashes in Western Australia. Three sets of crashes were examined. The first set comprised crashes that were identified as fatigue-related by the coders from Main Roads Western Australia. The assessors agreed that 75% (n = 15) were definitely fatigue-related and that the remaining 25% (n = 5) were possibly fatigue-related. The second set of crashes examined were those that were defined to be fatigue-related using the New South Wales RTA definition of a fatigue crash. The assessors agreed that 12% (n = 2) may have possibly been fatigue-related but that the remaining 88% (n = 15) were unlikely to be fatigue-related. This indicates that this definition produces a high rate of false positives.

The set of crashes coded as fatigue-related by Main Roads Western Australia were also examined to determine whether they fitted the New South Wales RTA definition of a fatigue crash. It was found that 17 out of 20 crashes (85%) fitted the definition. It appears that the New South Wales RTA definition captures many truly fatigue-related crashes, but it is too broad and thus also captures many non-fatigue-related crashes.

The third set of crashes was a random selection of all other crashes. None of these crashes were considered to be fatigue-related (n =35).

Cercarelli and Haworth (2002) concluded that

- The crashes recorded as fatigue-related in the Western Australian data set are more than likely fatigue-related, and therefore these records can be examined with some confidence when examining the role of fatigue.
- The New South Wales Roads and Traffic Authority definition appears to capture many truly fatigue-related crashes, but it is too broad and also captures many non-fatigue-related crashes. Therefore caution should be taken when using this definition to identify fatigue-related crashes.
- The information provided in the text box of the police forms is more useful than the information in the diagrams in identifying the role of fatigue in crashes.

Australian Transport Safety Bureau (ATSB) Operational Definition

The ATSB has developed an operational definition of fatigue (Dobbie, 2002) for identifying crashes as fatigue-related that can be used with fatality data from all States, including those that do not code crashes as fatigue-related on their police accident report form. Under the operational definition, fatigue-related crashes:

- Include single vehicle crashes that occurred during ‘critical times’ (midnight-6am and 2pm-4pm)
- Include head-on collisions where neither vehicle was overtaking at the time
- Exclude crashes that
    - Occurred on roads with speed limits under 80 km/h
    - Involved pedestrians
    - Involved unlicensed drivers
    - Involved drivers with BAC over 0.05%.

Unfortunately, in the report describing the outcomes of using this operational definition, drivers and riders are not separated in the analysis. Therefore it is not possible to assess whether the involvement of fatigue is higher or lower for motorcyclists.

4.2.4 Victorian crash data

The Victorian road crash dataset does not include any specific variable that indicates that fatigue contributed to the crash. There are, however, some variables that may be used to assess the extent of some factors or characteristics that have been found to be associated with fatigue (at least in studies of drivers). Circadian rhythms are one such factor. Figure 4.5 shows that the time of day pattern of motorcycle crashes in 2000-2004 was different for weekday and weekend crashes. On weekdays there was a general increase from 6am through to 6pm followed by a sharp decline, with some evidence of a morning peak hour effect. The temporal distribution of weekend crashes was bell-shaped, with an increase from 10am through to 4pm, followed by a decline. On both weekdays and weekends there were relatively few crashes in the circadian low period of midnight to 6am but large numbers of crashes in the afternoon circadian low period of 2-4pm. The extent to which these crash patterns reflect patterns of riding will be examined in a later section.

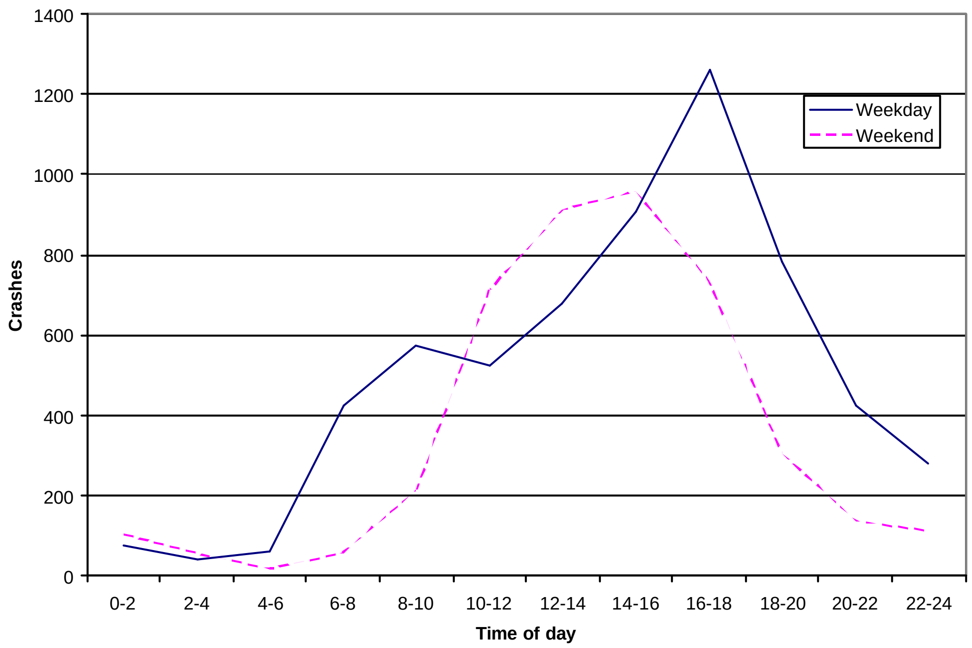

Figure 4.5 Number of motorcyclists in crashes in Victoria as a function of time of day on weekdays and weekends. Data for 2000-2004.

It is generally considered that fatigue is more common in single-vehicle crashes than multi-vehicle crashes. Figure 4.6 shows the time of day patterns for single vehicle motorcycle crashes in Victoria, which comprise 36% of weekday crashes and 62% of weekend crashes. The most striking feature of Figure 4.6 is the larger number of weekend crashes than weekday crashes from 10am to 6pm (despite there being 2.5 times as many weekdays as weekend days). On weekends, the temporal pattern of single-vehicle crashes is similar to that for all crashes, although with a more prominent peak between 2pm and 4pm. On weekdays, there is a gradual increase in crash numbers throughout the day, reaching a maximum between 4pm and 6pm. In terms of circadian low periods, there are still relatively few single vehicle crashes between midnight and 6am and much larger numbers between 2pm and 4pm, particularly on weekends.

However, circadian effects on alertness are not the only factors that are prominent contributors to crashes between midnight and 6am. Figure 4.7 shows that the number of riders with a BAC of 0.05% or greater was high during at least the first two hours of the circadian low period from midnight to 6am.

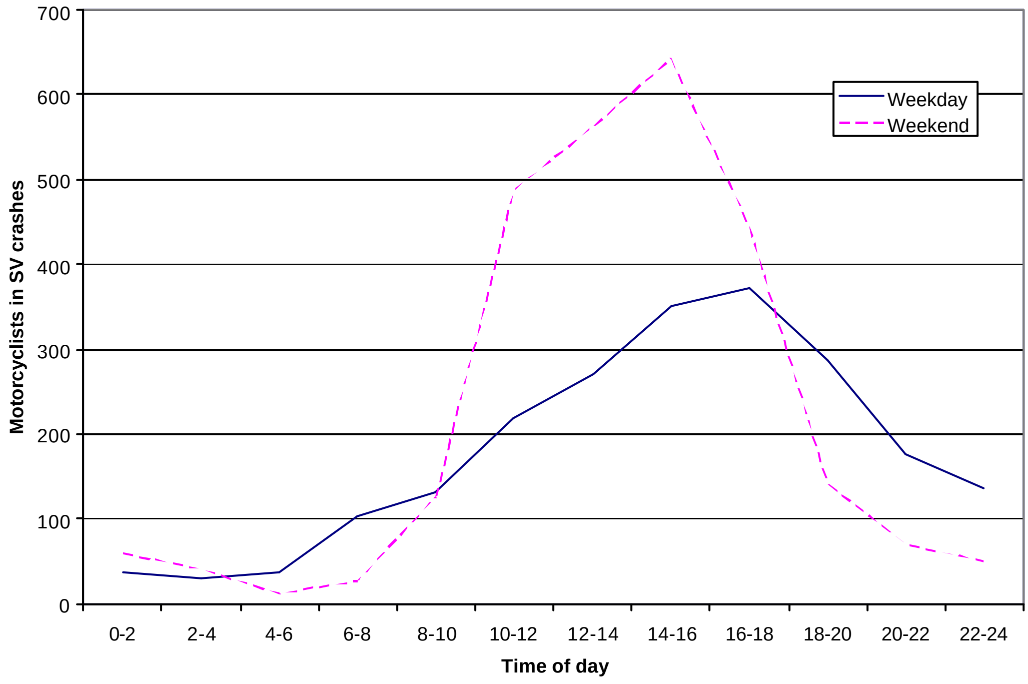

Figure 4.6 *Number of motorcyclists in single-vehicle crashes in Victoria as a function of time of day on weekdays and weekends. Data for 2000-2004.*

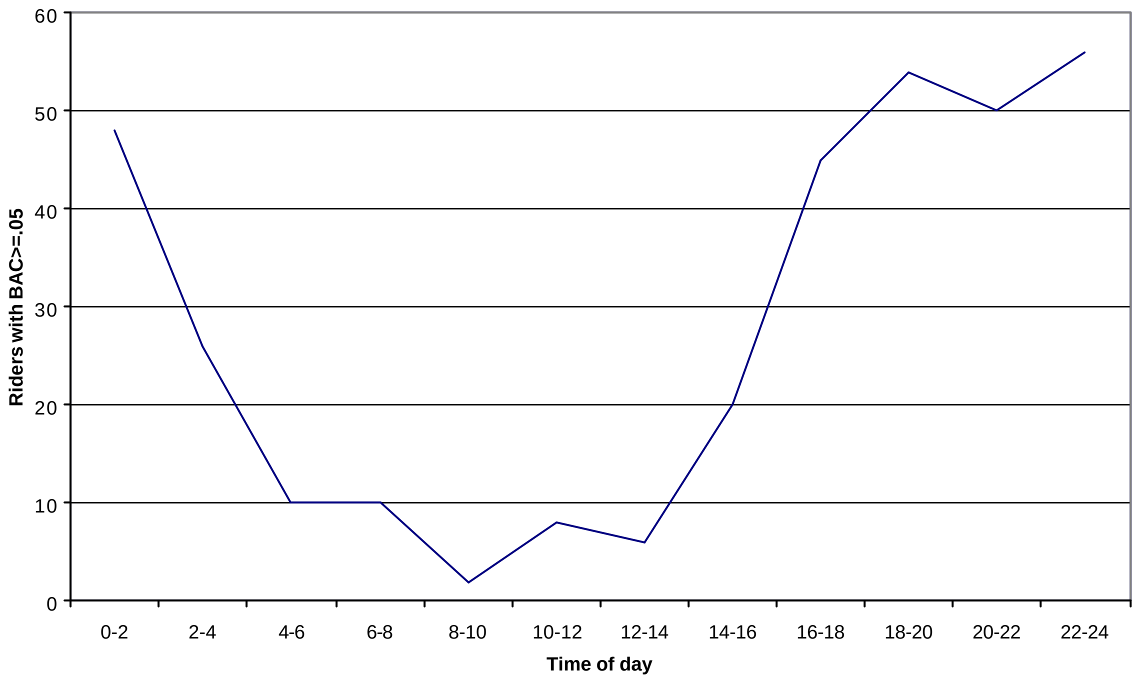

Figure 4.7 *Number of riders in crashes with BAC of 0.05% or greater in Victoria in 2000-2004 as a function of time of day.*

4.2 CORONERS REPORTS

In Victoria and in other States of Australia, all unexpected deaths are required to be reported to the Coroner. For some deaths, an inquest is conducted. In general, more information is available about the cause and circumstances of an unexpected death when an inquest is conducted. The Victoria Police provide an Inquest Brief to the Coroner in this circumstance. The Inquest Brief can include a range of material, most commonly:

- Statements from relatives, friends or employers regarding the events leading up to the crash
- Statements from eyewitnesses to the crash
- Statements by attending and investigating Police
- Statement by the doctor who pronounces life extinct
- Post mortem report
- Toxicology report
- Mechanical inspection report
- Photographs, plans and maps relating to the crash scene.

In identifying whether fatigue contributed to the crash, the statements regarding the events leading up to the crash can often be useful in assessing whether there was a lack of sleep or shiftwork or other activities that might have led to fatigue. The statements from eyewitnesses and police can establish whether the characteristics of the crash were consistent with those commonly associated with fatigue-related crashes (as defined by Horne & Reyner, 1995 and others). The post mortem and toxicology reports can help to rule out other contributors to the crash such as high alcohol or drug levels or natural disease or suicide (as can the statements from relatives and friends). The mechanical inspection report can establish whether a loss of control (for instance) related to mechanical problems with the motorcycle rather than rider fatigue.

As part of this research, a preliminary investigation of the usefulness of Inquest Briefs in identifying motorcycle fatigue was conducted by reviewing the Briefs for six single vehicle motorcycle fatalities which were attended by the Major Collisions Investigations Group. It should be noted that fatalities of this nature are not generally attended by MCIG. In general, the MCIG only investigates collisions where there are three or more fatalities or where there is potential for charges to be laid against a surviving driver.

The following conclusions were drawn from examination of the Inquest Briefs:

- The extent of detail regarding sleep and work activities prior to the crash appears to be greater, and sufficient to assess whether the rider was likely to be fatigued, if there is no other more obvious cause of crash.
- Details of the purpose of the trip are provided.
- The description of crash circumstances is good and almost always describes the length of the trip.
- Most reports give a good description of why rider lost control and therefore are able to rule out fatigue as a contributor to loss of control by identifying if excessive speed or stunts were involved.
- Details of road surface irregularities and road width are provided.
- In most instances, it is possible to be reasonably confident whether or not fatigue contributed to the fatality from the Inquest Brief

- In only one of the six Briefs examined was fatigue a possible contributor to the crash.

4.3 IN-DEPTH CRASH STUDIES

There is no unequivocal method for identifying the involvement of fatigue in crashes, as there is for alcohol. Researchers and crash investigators therefore often rely upon evidence of erratic driving immediately prior to the crash - crossing the centre line, running off the edge of the road and the frequency of lane excursions – and driver behaviour in the days leading up to the crash to indicate the involvement of fatigue. A number of special purpose studies have tried to estimate the involvement of fatigue and other factors in crashes (e.g. Enhanced Crash Investigation study, review of fatigue crashes on the Newell Highway). Similarly, there have been several in-depth motorcycle crash studies that provide at least some information about crash and pre-crash factors that could be relevant to examining the role of fatigue in these crashes.

The Victoria Police Major Collisions Investigation Group Study of Fatal and Serious Injury Motorcycle Collisions (Alway & Poznanski, 2003) collected details of 47 crashes in Victoria from May 2002 to April 2003. While the report describes the characteristics of the crashes and their locations, there is little information provided that is relevant to the possible involvement of fatigue in the crashes (e.g. no information about prior sleep or work activities). However, the report notes that in all of the crashes occurring between midnight and 6am, alcohol or cannabis was present in the rider's bloodstream. Thus fatigue is not likely to have been the major contributor to crashes occurring during this circadian low period.

In the motorcycle crash case-control study (Haworth et al., 1997), both crashed riders and controls were asked about the length of trip and details of all trips in the previous 24 hours. Unfortunately, these data were not analysed. Consistent with the Victoria Police study, the research found that the time of day pattern of motorcycle crashes differed according to whether the rider had been drinking. Only 5% of crashes where the rider had a BAC less than or equal to 0.05% occurred between midnight and 6am, compared with 32% of crashes where the rider had a BAC greater than 0.05% (see Table 4.1). The proportion of crashes between 6pm and midnight was also higher when the rider BAC was greater than 0.05%. Thus, many of the crashes that occurred during the circadian low period of midnight to 6am were alcohol-related, rather than solely being a consequence of fatigue.

4.4 HOSPITAL DATA

Figure 4.1 shows that there is potentially more complete coverage of motorcycle crashes in hospital data than in Police-reported crash data. Hospital data also provide good injury information that can be used to measure the cost of the crash (e.g. in terms of bed days of stay) and can be used in conjunction with Police data to investigate effects of vehicle and roadway and roadside design on injury outcomes. However, hospital data do not indicate clearly the number of crashes resulting in hospital admission, the number of people in each crash, the pre-crash circumstances or the crash characteristics. Thus, hospital data provide a useful measure of the incidence of injuries to motorcyclists but little information about the circumstances in which the injuries occurred.

Table 4.1 The times of day that the crashes occurred - all crashes and where the rider had BAC>.05.

Time of day	Percent of crashes		
	BAC<=.05 (n=124)	BAC>.05 (n=22)	All crashes (n=222)
Midnight to 6 am	5	32	7
6 am to midday	27	14	24
Midday to 6 pm	47	18	42
6 pm to midnight	22	36	28
Total	100	100	100

4.5 MOTORCYCLE EXPOSURE INFORMATION

The contribution of fatigue to motorcycle crashes is at least partly determined by the extent of exposure of riders to the factors that have been shown to contribute to fatigue. One of the strongest factors shown to contribute to fatigue is the existence of circadian low periods. Given the underlying physiological nature of circadian rhythms and the wide range of performance that they have been shown to affect (e.g. errors in manufacturing, failures of monitoring complex equipment), then it is likely that the performance of motorcyclists will be affected by circadian low periods.

Few studies have collected information about the time of day patterns of motorcycle riding. Haworth et al. (1997) counted the numbers of motorcyclists (and other vehicles) passing crash sites as part of the collection of control data for the Melbourne case-control study of motorcycle crashes. The crash risks associated with particular times of the day could not be directly estimated in this study because control recruitment was matched to the time of day that the crash occurred.

During the recruitment of controls, traffic counts were made in the direction in which motorcyclists were being stopped. These counts and the calculated hourly volumes of all traffic and motorcycles are summarised in Table 4.2. Given that the location and timing of the control sites were matched to the location and timing of the crashes, the locations are different for the different time periods. The mean number of motorcycles per hour was greatest between 6am and 6pm on weekdays and weekends. Weekday daytime motorcycle volumes were significantly greater than weekend daytime or weekend night-time (6pm-6am) volumes ($F(3,216)=6.4$, $p<.01$, Bonferroni tests $p<.05$). The proportion of vehicles that were motorcycles was higher during daytime on weekends than any of the other time periods ($F(3,216)=6.7$, $p<.01$, Bonferroni tests $p<.05$).

Table 4.2 Motorcycle and general traffic volumes at control sites. From Haworth et al. (1997).

TIME PERIOD	Number of sites	Mean no. motorcycles per hour	Mean no. other vehicles per hour	Proportion motorcycles
Weekday daytime	98	4.4	883	0.0050
Weekend daytime	45	3.6	599	0.0059
Weekday night-time	34	1.5	416	0.0036
Weekend night-time	40	2.5	623	0.0040
OVERALL	217	3.4	703	0.0049

Notes:

1. Weekday daytime=6am to 6pm Monday-Friday, Weekend daytime=6am to 6pm Saturday-Sunday, Weekday night-time=6pm to 6am Sun-Mon, Mon-Tue, Tue-Wed, Wed-Thur, Weekend night-time=6pm to 6am Thur-Fri, Fri-Sat, Sat-Sun.
2. The time period corresponds to the time of occurrence of the crash which was the mid-point of the 90 minutes of sampling of motorcycles. Therefore, if the crash occurred at 5.50 pm on a Monday, the time period would be classed as Weekday daytime, even though 35 minutes of sampling would have occurred after 6 pm.
3. Other vehicles were counted for 15 minutes and the value multiplied by four to give an hourly value.

For this report, additional analyses of the data collected by Haworth et al. (1997) were conducted to provide exposure estimates that could be used in conjunction with the crash data to assess whether crashes were over-represented during the circadian low periods. Unfortunately, when broken down into 2-hour periods, the exposure data is based on observations at a relatively small number of sites on a variety of road types and so may not be robust. Thus, the results which follow should be considered to be indicative of likely general patterns that would need to be confirmed by collection of more extensive exposure information.

Figure 4.8 shows the motorcycle counts per hour summed over 2-hour periods. The time of day patterns were markedly different on weekdays and weekends, with the highest volumes in traditional peak traffic periods on weekdays. Overall, the average total number of motorcycles observed during the circadian low period of midnight to 6am was 5.2 on weekdays and 5.4 on weekends. During the circadian low period of 2 to 4pm, the average total number of motorcycles observed was 3.9 on weekdays and 3.0 on weekends.

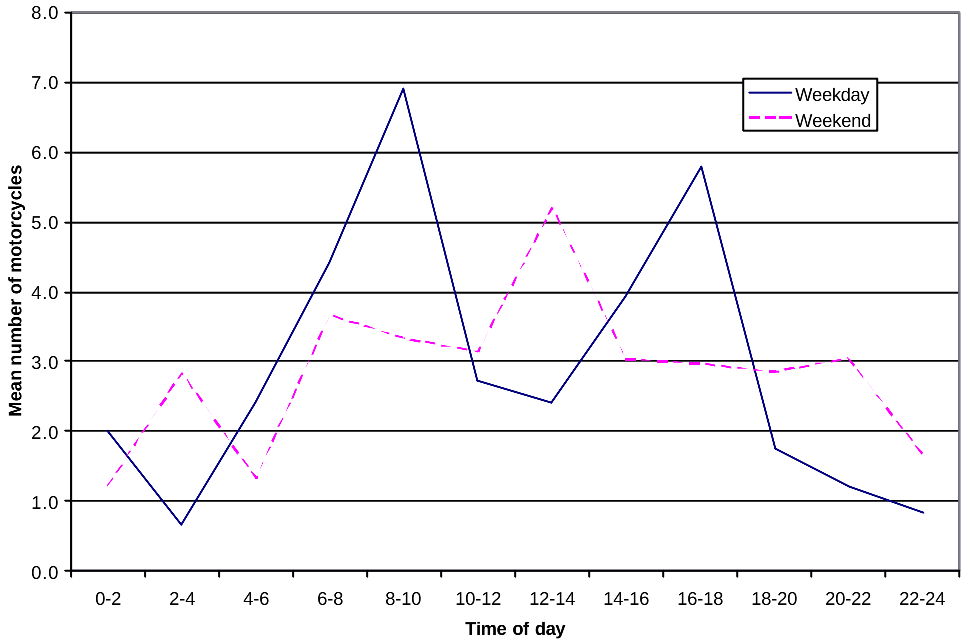

Figure 4.8 *Mean number of motorcycles observed per hour at control sites as a function of time of day on weekdays and weekends. Data collected by Haworth et al. (1997) as part of Melbourne case-control study of motorcycle crashes.*

4.5.1 Seasonal trends in motorcycle volumes

Chapter 3 presents some preliminary evidence that extremes of heat and cold may result in reduced rider alertness. There is little data that directly bears on the prevalence of these factors in riding (or in crashes).

Heat and cold affect the likelihood of riding as well as rider alertness. In Victoria, many older riders report that they only ride during summer (Haworth et al., 2002). The motorcycle case-control study reported seasonal trends in motorcycle volumes at control sites from February 1996 to January 1997. Figure 4.9 shows that the mean number of motorcycles per hour was somewhat higher in February than in the other months but that there was no clear seasonal effect on motorcycle volumes. Motorcycle volumes on the weekend showed a more marked seasonal effect than those on weekdays (see Figure 4.10). In general, weekend volumes were higher than weekday volumes during January to March but lower during the cooler months. This suggests that recreational riding is much more seasonal than commuter riding.

Thus, the contribution of cold to motorcycle fatigue is mitigated by many recreational riders being less likely to ride at colder times of the year.

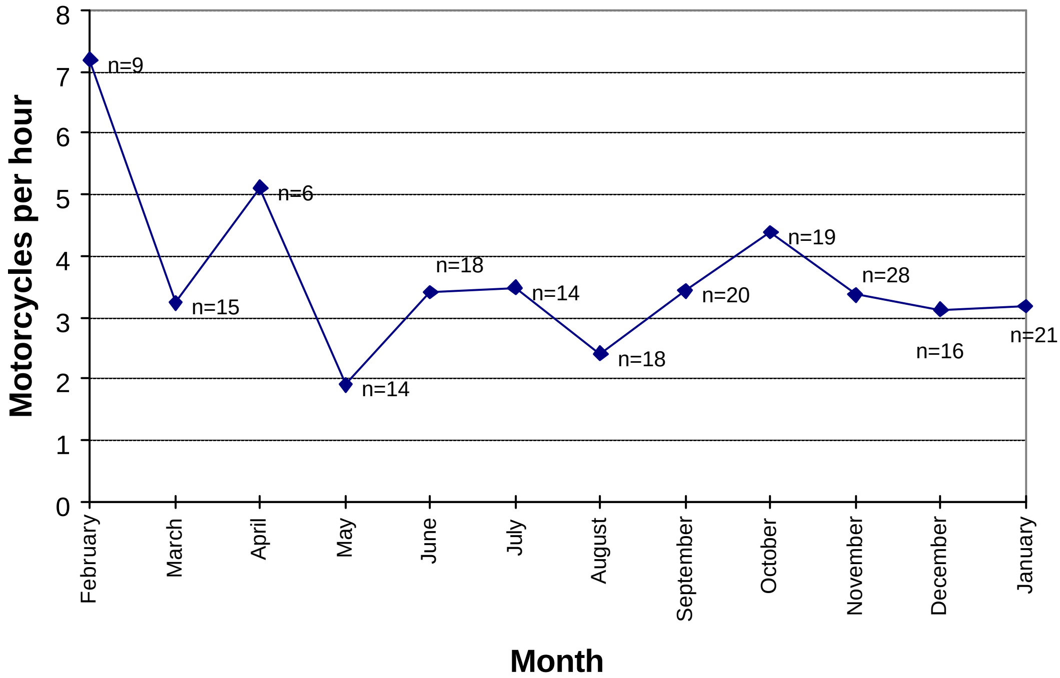

Figure 4.9 *Mean number of motorcycles per hour for control sites in each month of the year. The number of sites at which motorcycles were counted in each month are labelled on the figure. From Haworth et al. (1997).*

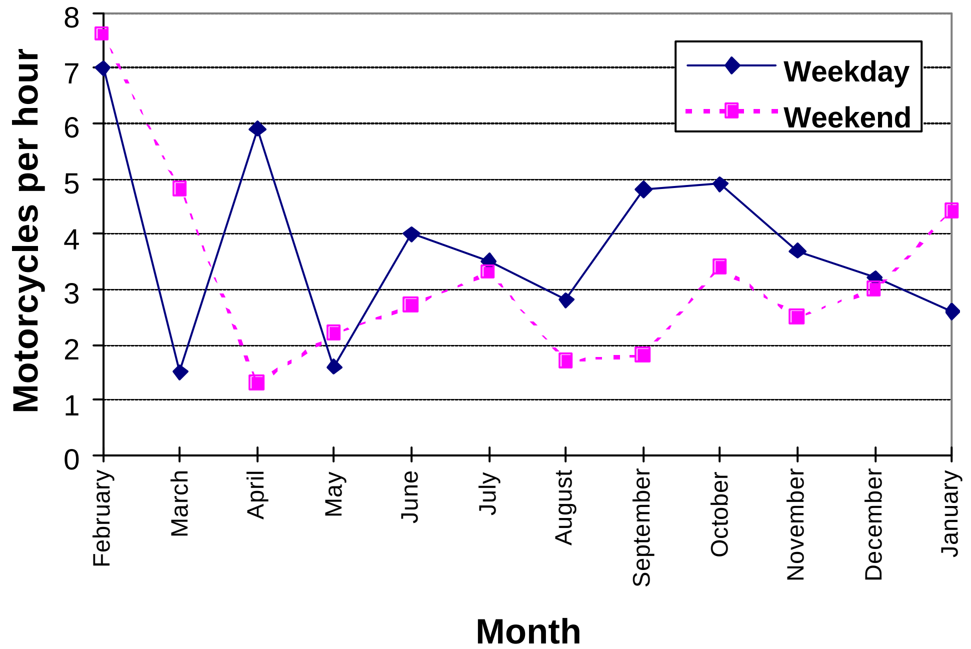

Figure 4.10 *Mean number of motorcycles per hour on weekdays and weekends for control sites in each month of the year. From Haworth et al. (1997).*

4.5.2 Influences of weather on motorcycle exposure

The weather conditions during each control session were recorded by Haworth et al. (1997). Table 4.3 summarises the weather conditions during the first control session for each case. Repeat sessions were excluded to avoid bias from more commonly repeating rainy controls than dry controls. While the means suggest that volumes were less when it was heavy rain or cloudy or overcast than when it was dry, a one-way analysis of variance showed that the volumes for each type of weather did not differ significantly, $F(4, 216)=1.6$, $p>.10$.

Table 4.3 Motorcycle volumes as a function of weather conditions. From Haworth et al. (1997).

Weather	Mean no. of motorcycles per hour	Standard deviation	No. of cases
Fine	3.8	3.8	126
Cloudy or overcast	2.8	3.4	62
Light rain or drizzle	3.9	5.1	19
Heavy rain	1.1	1.0	7
Fog	5.3	5.7	3

5. ESTIMATING THE CONTRIBUTION OF FATIGUE TO MOTORCYCLE CRASHES

The contribution of fatigue to motorcycle crashes can be expressed in terms of the proportion of motorcycle crashes in which fatigue was a contributing factor or in terms of a relative risk that describes the increase in the likelihood of a crash for a fatigued rider compared to an alert rider. The first measure is conceptually simpler and will be discussed first in this chapter. Some comments will then be made about the second type of measure.

While it is not the focus of this report, it is likely that fatigue on the part of the other driver contributes to some multi-vehicle motorcycle crashes.

5.1 ESTIMATING THE PROPORTION OF MOTORCYCLE CRASHES THAT ARE FATIGUE-RELATED

Given the limited scientific information currently available regarding the magnitude of the contribution to motorcycle fatigue of particular factors, one of the few ways of estimating the proportion of motorcycle crashes that are fatigue-related is to apply one of the algorithms that have been developed to identify fatigue in car and truck crashes to motorcycle crash data.

The ATSB definition was developed to provide a common, objectively based identification of fatigue-related road crashes that would be useful in monitoring these crashes and comparing trends over time or between regions. Dobbie (2002) cautions that the operational definition was not designed to measure the absolute number of fatigue-related crashes, but rather to serve as a reliable indicator.

When the ATSB definition is applied to the Victorian motorcycle crash data for 2000-2004, 14.6% (39) of the fatalities are identified as ‘fatigue-related’. In comparison, Dobbie (2002) reported that 15.6% of all fatal crashes in Victoria in 1998 were ‘fatigue-related’ using the ATSB definition. Thus, overall the ATSB definition appears to identify similar percentages of motorcycle and all fatal crashes as ‘fatigue-related’.

The details of the ATSB definition are presented in Section 4.1.3. Broadly, the crashes contributing to this definition include single vehicle crashes in critical circadian periods and head-on, not overtaking crashes. Of the Victorian motorcycle fatalities identified as ‘fatigue-related’, about 20% are single vehicle crashes in the critical periods and the remaining 80% are head-on, not overtaking crashes. In contrast, Dobbie (2002) found that 37.5% of the Australian fatal crashes (data were not presented for Victoria) identified as ‘fatigue-related’ were single vehicle crashes and 62.5% were head-on, not overtaking crashes. Thus, the ‘fatigue-related’ motorcycle crashes identified by the ATSB definition appear to include relatively fewer single vehicle crashes in the critical periods and relatively more head-on, not overtaking crashes than would be found for all fatal crashes.

It is interesting to speculate that many of the head-on, not overtaking motorcycle crashes may have had excessive speed as a major contributor, rather than fatigue. If this is the case, then the ATSB definition probably overestimates the proportion of fatal motorcycle crashes that are fatigue-related.

Applying the ATSB definition to the Victorian motorcycle crash data of all severity levels is somewhat difficult since BAC data are missing for most riders. However, if it is assumed that BAC is zero where missing, applying the definition to data for 2000-2004 identifies 8.4% (866) of motorcycle crashes as ‘fatigue-related’. About three-quarters of the ‘fatigue-related’ crashes are single vehicle crashes during the critical time and the remaining quarter are head-on not overtaking crashes. This is a very different composition to that obtained from analysing the fatal crashes.

5.2 THE RELATIVE RISK OF FATIGUED RIDING

In this section, an attempt will be made to estimate the relative risk of riding when fatigued compared to riding when alert and well-rested. Given the present state of knowledge about fatigued riding, this estimate may be imprecise but will provide some guidance on the likely importance of fatigue as a risk factor for motorcycle riders and on ways of collecting better data.

The review of the literature and data relevant to fatigue in motorcycling lead us to conclude that the data are not available to allow the risk of motorcycle fatigue to be calculated in any reliable analytical way. The only approach that is possible under the current state of knowledge in this area is to make broad estimates based on a set of assumptions and then use expert judgement to test the plausibility of these estimates.

The simplest and most robust assumption is that circadian factors are the only major contributors to motorcycle fatigue and that these affect riders and increase crash risk in the same way as they do car drivers. This assumption is based on the view that circadian factors are a basic biological phenomenon that affects performance over a very wide range of tasks and therefore should affect riders and drivers similarly.

A drawback of the circadian approach is that a number of other contributors to crashes show time of day effects that are not related to circadian changes in alertness. For example, the involvement of alcohol in crashes is greater at night and traffic density also differs by time of day.

5.2.1 Calculation of exposure-weighted crash index

The approach taken to estimating the fatigue crash risk associated with circadian factors was to divide crash involvement by exposure in each period of the day to form an exposure-weighted crash index. Similar approaches have been used in the past to estimate the contribution of reductions in alertness in circadian low periods to crashes of cars and trucks (Harris, 1977; Mackie & Miller, 1979).

The number of motorcyclists in crashes in each 2-hour period of the day calculated from the Victorian data for 2000-2004 (as shown earlier in Figure 4.5) was divided by the mean number of motorcyclists observed by Haworth et al. (1997) in the same period of the day (as shown earlier in Figure 4.8). While the absolute values of the crash index have little direct meaning, the pattern across the day indicates the relative crash involvement of motorcyclists across the day, given the amount of riding that occurs at that time of day. It should be remembered that the exposure data in 2-hour periods was based on small numbers of sites for some time periods and therefore the crash index may not be robust, given the constraints of the exposure data on which it relies.

Bearing in mind these caveats, the crash index is presented in Figure 5.1. The shapes of the curves differ noticeably between weekdays and weekends. On weekdays, the crash index generally increases throughout the day, being lowest in the midnight to 6am period and peaking between 6 and 8pm. It shows no clear evidence of peaks in circadian low periods. On weekends, the highest values of the crash index occur between 10am and 6pm, with the highest value being at the circadian low point of 2 to 4pm.

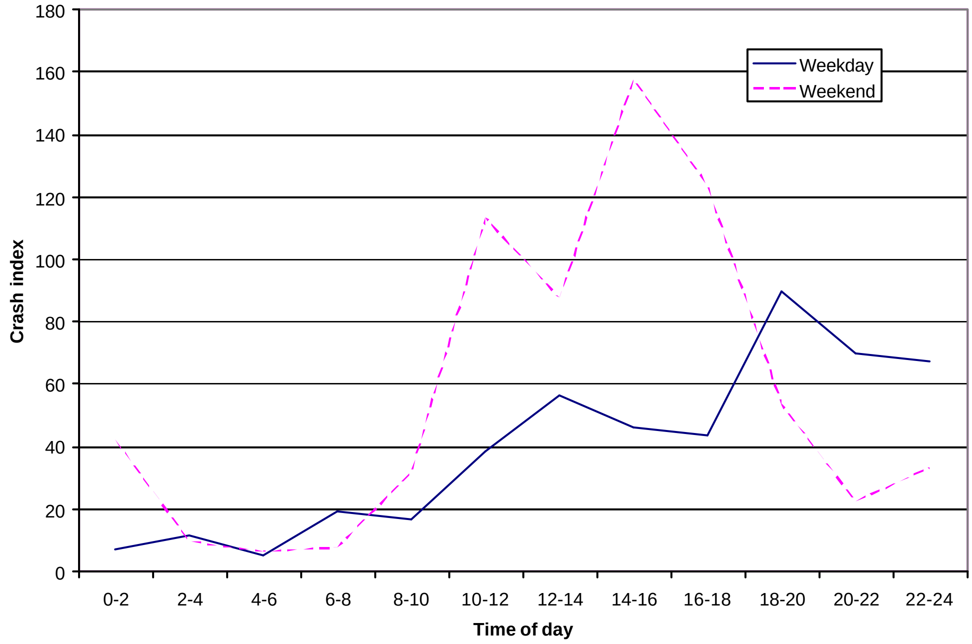

Figure 5.1 Crash index by time of day on weekdays and weekends. Crash index compiled from number of crashes during that period divided by exposure measure and corrected for more weekdays than weekends.

Figure 5.2 shows the crash index when only single-vehicle motorcycle crashes are included. It is remarkably similar in shape to the all crashes index, showing a peak only for the circadian low period of 2pm to 4pm on weekends.

Thus, this approach has not provided any clear evidence of an increased crash risk during the circadian low period of 12 midnight to 6am. While there is some evidence of an increased crash risk from 2pm to 4pm, this is only evident on weekends and may reflect other factors. We do not know what these factors might be, but they could potentially include such factors as more riding by less experienced riders or more riding by risk-taking riders (or even the after-effects of liquid lunches).

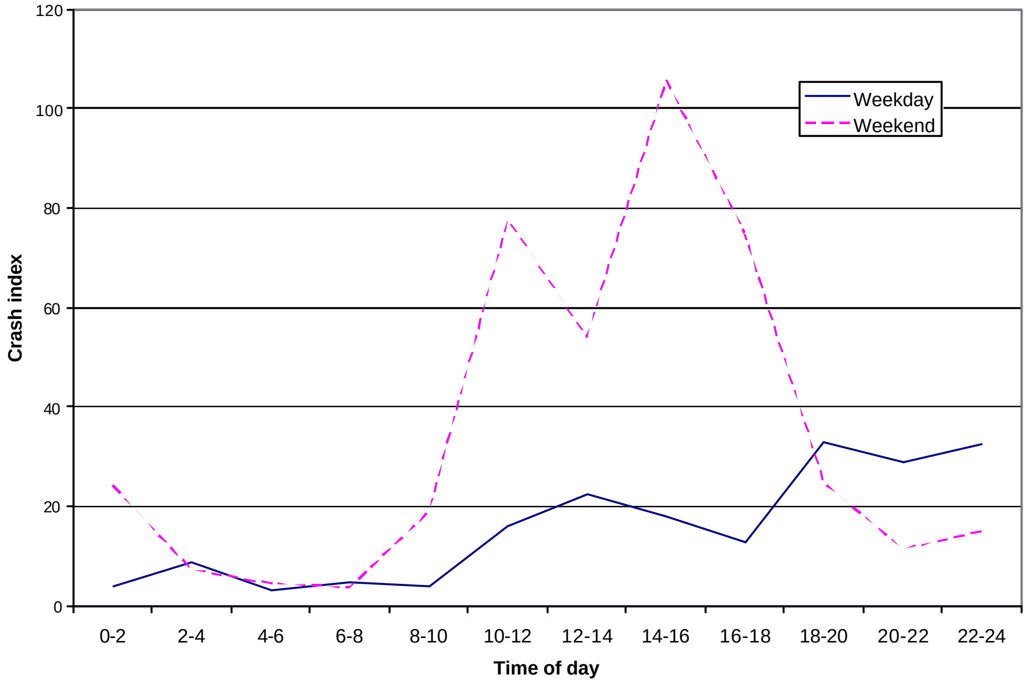

Figure 5.2 Single-vehicle crash index by time of day on weekdays and weekends. Crash index compiled from number of crashes during that period divided by exposure measure and corrected for more weekdays than weekends.

6. CONCLUSIONS AND RECOMMENDATIONS

The literature review found that while considerable research has addressed issues related to fatigue in car and truck drivers, fatigue in motorcycling has received very little attention. Currently, we do not have the information needed to draw reliable conclusions regarding the magnitude of the effects of factors that potentially contribute to motorcycle fatigue or to assess the real contribution of fatigue to motorcycle crashes or the crash risk associated with riding while fatigued. However, the limited research suggests that fatigue is likely to be an issue in motorcycling, and therefore more knowledge of the phenomenon is needed to allow countermeasures to be developed.

More information is needed regarding:

- The extent to which riders experience both mental and physical fatigue and the circumstances under which these effects occur (e.g. which is the bigger problem, objective measures of performance degradation)

- The rider, vehicle and trip factors that influence the development of mental and physical fatigue (e.g. do novice riders develop mental fatigue more quickly?)

- The extent to which riders believe fatigue has contributed to their crashes and near-misses

- Methods of preventing or reducing mental and physical fatigue.

This list is not exhaustive but provides some guidance for priorities in future research.

Given the large number of questions that need to be answered, there is a need to prioritise the research effort, concentrating on relatively low cost methods of collecting information that can be then used to develop hypotheses to test in future, more sophisticated, research.

It is recommended that the following research activities be undertaken in the short term:

- Further analysis of motorcycle crash data to assess the likely validity of using the ATSB fatigue definition with motorcyclists. It may be useful to conduct these analyses with data from NSW and Queensland where the effects of screening out speed-related crashes could be examined.

- Examination of motorcycle fatality data from the National Coronial Information Service to assess whether this data allows a better estimation of the role of fatigue in fatal motorcycle crashes. However, it should be noted that the role of fatigue and other factors may not be the same in fatal crashes as in crashes of lower severity, thus limiting the extent to which these results can be generalised.

- Surveying riders regarding their experience of fatigue when motorcycling. This could be undertaken as a mail, telephone or Internet survey.

- Undertaking testing of riders during trips to measure subjective levels of fatigue as a function of trip length, time of day etc. This could be undertaken naturalistically or designed as an experiment to provide additional control over confounding variables.

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APPENDIX 1: REVIEW OF INQUEST BRIEFS FOR MOTORCYCLE CRASHES

Kimberlin

- statements addressed that no stock or kangaroos were likely to have strayed onto the road
- includes distance to roadside tree that was hit
- tyre marks and likely braking
- weather conditions and possible influence of wind blowing rider off path
- detail about road surface conditions
- discusses sleep prior to the crash – 5 hours sleep in the 24 hours prior to the crash
- discusses shiftwork pattern and normal sleeping pattern for the deceased
- familiarity with the road
- mention of past epileptic fits
- broken helmet
- stated no suspicion of suicide
- no mechanical defect with motorcycle

King

- dark, wet road, poor visibility
- Circumstances of the crash (rider to left of vehicles in same lane, median)
- More information about crash circumstances because there were witnesses
- No brake lights prior to the collision with concrete median
- Not travelling at an excessive speed
- Traffic island hard to see because street light at that location was not functioning
- Familiar with the road
- Unroadworthy rear tyre (Lack of tread)
- Speedometer reading
- Does not include any information about sleep prior to crash or shiftwork etc.

Le Prest

- details of sleep and activity prior to the crash are provided
- Details of experience with the particular motorcycle
- Discounted suicide
- Description of crash by witness
- Evidence from witnesses he wasn't speeding
- Police believe he lost control when changing lanes on a curve at 100 km/h
- Unroadworthy front tyre (lack of tread)

Williams

- 0.18 BAC plus carboxy THC – high level which if he didn't smoke prior to collision indicated regular use
- High speed reported by witnesses
- Windy weather
- Clipped kerb of centre median
- Classed as single vehicle fixed object, despite impact between mcycle and parked car
- Describes activities on the day of collision but not sleep patterns prior
- Established no road surface factors contributed to loss of control
- No mechanical faults
- Didn't talk about type of helmet

Walsh

- gives details of learner course completed by deceased
- Motorcycle was borrowed and deceased had never ridden it before
- Gives details of make and model (a dangerous one)
- almost no on-road riding experience although held L permit for six months
- Describes type of helmet
- Gave details of road surface condition, gutters etc
- Only a short trip

Vautin and Collins

- speed of about 120 km/h in built-up area, doing a "mono", then lost control and hit a parked car
- Statement from police who observed similar riding behaviour by deceased and gave an infringement the previous year
- Pillion was an unlicensed rider
- Information on usual consumption of marijuana
- Suicide unlikely
- Very short trip
- Helmet strap not done up
- Evidence of heavy braking